Cutting technic for *Pinus elliottii* plantation of the multi-benefit management pattern

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Abstract: The cutting technic for the *Pinus elliottii* plantation of the multi-benefit management pattern in the hilly region of Jiangxi Province was studied by establishing the model of growth progress according to Richards function and simulating the tending cutting on computer by use of dynamic programming. The results showed that the best time for the initial thinning was at tree age of 8-10 and final cutting was at tree age of 25. The optimal thinning project was 3 times of thinning cutting including the first thinning, and the thinning time was at tree ages of 8, 12 and 16, respectively. Their thinning intensities were separately 950, 700 and 300 trunks per hectare, and the preserved density was 550 trunks per hectare until the final cutting

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Introduction

Pinus elliottii was an introduced speces and generalized successfully in Jiangxi Province in south of China. According to the statistical figure of forest inventory in 1999, the forestation area of *Pinus elliottii* in Jiangxi was up to 5.4×10^5 hm^2. *Pinus elliottii* has been a key tree species of afforestation and plays an important part in development of the regional economy. At present, along with the increase of people's recognition on ecological environment construction, the multi-benefit management pattern has become an important pattern of five popular management patterns of the *Pinus elliottii*. However, for managing the real forest scientifically and bringing its ecological, economic and social benefits into full play, there are still some theoretical problems and technological programs that need to be studied and resolved urgently. Density control technic is an optimal method to promote the growth of forest. In this paper, the cutting technic for the *Pinus elliottii* plantation of the multi-benefit management pattern was studied for the purpose of guidance of forest management.

Study area

Jiangxi Province is located in the middle and down of Yangtze River (24°29'-30°05' N, 113°35'-118°29' E). The total land area of the province is 166 947 km^2, of which the hilly region is about 88 482 km^2, making up 53% of the total area, and is an important basis for managing the stands of multi-benefit management pattern.

The climate of Jiangxi Province is characterized by sub-tropical monsoon. Annual mean precipitation is 1 351-1 934 mm, annual mean temperature 6.3-19.5°C, annual mean sunlight period 1 482-2 085 h, and frost-free period is 240-307 d per year. The zonal soil types are red soil, yellow soil, and yellow-red soil. Moreover, mountain yellow-brown soil, mountain meadow soil, purple soil, lime soil are also distributed in Jiangxi. The red soil is distributed all over the hilly and hillock region, low hilly and high hilly region with elevation in range of 500-600 m. The depth of red soil is more than 60-100 cm, and the pH scale ranges from 4.5 to 5.5.

Data collection and study methods

The stands of *Pinus elliottii* in the middle site, with site indexes in range of 13-17, were studied in hilly region. Totally 55 plots were set up in 9 cities, of which, 8 plots were located in Ganzhou City, 13 in Jian City, 5 in Fuzhou City, 4 in Nanchang City, 7 in Yichun City, 3 in Xinyu City, 6 in Jingdezhen City, 4 in Shangrao City, and 5 in Jiujiang City. The general inventory was conducted in evéry purposive sample plot and one standard tree was chosen for stem analysis.

Model of tree growth

The growth progress of tree was cumulative growth and it would be presented with "S" curve (Cheng *et al.* 1991).

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Many studies showed that the suppleness and adaptation of Richards function were better for describing the tree growth. Richards function was used in forestry research extensively, and many researches were brought to success since Copper (1961) introduced it into the study of forest growth in 1931 firstly (Luo 1989; Chen 1997; Wang *et al.* 2000).

The basic form of Richards function is

$$y = a(1-be^{-kt})^{\frac{1}{1-m}}$$

where, y is growth factor, i.e. tree height (H), breast-height diameter (D), basal area (G), volume (V), and so on; a is the limited value of growth factor; b is the value of y while t=0; k is growth rate with a and m; m is the type of the growth function.

Its general form used to simulate the growth progress of tree is $y = a(1-e^{-kt})^{\frac{1}{1-m}}$.

Modeling methods for thinning cutting

Taken ecological benefit of the stand into account and taken the maximum of economic value of stand as the optimal index, the simulating tests were conducted on computer by use of dynamic programming for different first cutting age, cutting intensity, and cutting time. Its detail methods refer to literatures of Cheng *et al.* (1991) and Beijing Forestry University (1987).

Results and analyses

Growth model, first thinning and final cutting for *Pinus elliottii* plantation

Data for modeling

The values of breast-height diameters of the standard trees chosen for stem analysis were matched with those of height and volume. Data used to establish height model were from series of height increment of those trees. And the data of breast-height diameter increment and volume increment were treated with the following functions.

(1) Regression functions on diameters and volumes were established, respectively.

$$D_{ob} = 0.9596824 + 1.106852\, D_{ib} \qquad R=0.9873 \quad (1)$$

$$V_{ob} = 0.0013 + 1.2011 V_{ib} \qquad R=0.9647 \quad (2)$$

where, D_{ob} is diameter outside bark, and D_{ib} is diameter inside bark. V_{ob} is volume outside bark, and V_{ib} is volume inside bark.

(2) Series of breast-height diameter increment inside bark of the standard trees chosen for stem analysis were transformed to series of that outside bark, and series of volume increment inside bark of those trees were transformed to series of that outside bark. Series of breast-height diameter and volumes outside bark were the data that were used to establish growth models. The data outside bark were usually obtained from field survey, and the data inside bark were obtained by stem analysis.

Growth models of height, breast-height diameter and volume

We used the formula, $t_{1.3} = -\frac{1}{k}\ln(1-\frac{1.3}{a})^{1-m}$ (Cheng *et al.* 1991), which was established based on Richards function, to calculate the age of tree with a height of 1.3 m. According to the series data of height growth from 55 individuals of stem analysis, the average age for the trees with height of 1.3 m was 2. Then, growth processes of breast-height diameter, height and volume of *Pinus elliottii* were separately simulated. The results were shown in Table 1.

Table 1. The simulating values of Richards function parameters based on standard tree of *Pinus elliottii* from middle site class

Factors	Parameters					Standard error	Correlation coefficient
	a	m	k	ak	T_i		
Breast-height diameter	22.85124	0.516281	0.128205	0.9660621	8	0.1152	0.9763
Height	15.26216	0.389723	0.106560	0.5851295	5	0.0657	0.9852
Volume	0.23040	0.887254	0.156452	0.0095500	12	0.1216	0.9634

Note: In the above Table, $\overline{ak} = \frac{ak}{2m+2}$ was average effective growth, and $T_i = \frac{1}{k}\ln\frac{1}{1-m}$ was the time at turning point of growth.

Thus the growth model of breast-height diameter could be expressed by

$$D = 22.85124\,(1-e^{-0.128205\,(t-2)})^{\frac{1}{1-0.516281}} \qquad (3)$$

Height growth model could be expressed by

$$H = 15.26216\,(1-e^{-0.106560\,t})^{\frac{1}{1-0.389723}} \qquad (4)$$

Volume growth model could be expressed by

$$V = 0.23040\,(1-e^{-0.156452\,t})^{\frac{1}{1-0.887254}} \qquad (5)$$

Cutting ages for first thinning and the final cutting

Parameter a determined the final values of growth factors (Cheng *et al.* 1991). From Table 1, it was shown that

the average height of *Pinus elliottii* was about 15 m, average breast-height diameter was about 23 cm and average final volume was about 0.23 m^3. The value of *ak* showed that the annual average effective height growth, breast-height diameter growth, and volume growth were about 0.6 m, 1 cm, and 0.0096 m^3, respectively.

From the value of parameter, the time (T_i) of the annual breast-height diameter growth, annual height growth and annual volume growth to reach the maximum were at tree age of 8, 5, and 12 years, respectively. Considering the fact of real forest growth that there exists serious differentiation in individual tree in forest, we should not take fastigium of annual volume increment as time of first thinning cutting. Instead, the first thinning time of the *Pinus elliottii* plantation for the multi-benefit management pattern determined was at tree age of 8-10 years.

Quantitative maturity is that while average volume increment equals to annual volume increment (Beijing Forestry University 1987). And that of the *Pinus elliottii* plantation, obtained from transform of formula of $dv/dt=v/t$, was at age of 23. To defer the time of final cutting for one or two years is helpful to improving the quality of timber as it is of advantage to pick resin. Thus the final cutting time of the *Pinus elliottii* plantation for multi-benefit management pattern could be confirmed to the tree age of 25.

Simulation of thinning cutting on computer and the strategy of thinning cutting

Thinning cutting is one of important measures for forest management. Proper thinning could adjust stand density, improve forest environment and promote growth of preserving tree. And it is also an important means to keep optimal function for water conservation, and to increase outputs of woods and resin per unit of area. Thinning cutting technic includes determination of first-thinning age, intensity and cycling period, which interacted with or affected by the forest management density.

Theoretically, it would be ideal to carry out thinning cutting in a shorter cycle and a lower intensity. However, the project of annual thinning cutting is always impossible to be carried out in practice because there are various limits, especially the limits that directly come from management motive, transportation force and market demand for undersized woods. Results from production and research showed that the times of thinning cutting should not be over four and that one times of thinning cutting could not attain the aim of intensive management, achieve higher income and promote soil protection and water conservation. Therefore, keystone of discussion is various thinning cutting projects.

Thinning cutting was simulated on computer by use of dynamic programming based on first thinning cutting, intensities and times of thinning cutting. Low-thinning cutting was more suitable for the *Pinus elliottii* plantation. The suitable range of management density for the *Pinus elliottii* plantation of multi-benefit management pattern on the hilly region of Jiangxi Province was studied in reference of Wang *et al.* (2001). Taken that suitable range of management density as the control factor, modeling tests based on various thinning cutting projects were done in terms of rules of feasibility, rationality and optimal benefit. The results were shown in Table 2.

Table 2. Total harvests of various thinning cutting projects

Projects	Times of thinning cutting	Ages of thinning cutting	Intensities of thinning cutting /trunk·hm^{-2}	Forest status of 25th year					
				Average diameter /cm	Average height m	Trunks per hectare	Value of total biomass /yuan	Value of total resin /yuan	Total value /yuan
I	2	8, 15	900,900	24.1	12.9	700	52822.1	103265.1	156087.2
II	2	10, 15	1000,900	23.6	12.7	600	43631.9	74722.8	118354.7
III	3	8, 12, 16	950,700,300	27.2	14.1	550	59753.0	133024.2	192777.2
IV	3	8, 13, 18	1000,650,300	26.5	13.9	550	59235.9	125206.6	184442.5
V	3	10, 14, 18	1300,400,300	25.5	13.5	500	48240.2	94563.3	142803.5
VI	3	10, 15, 20	1350,350,200	24.7	13.2	600	49163.6	98105.3	147268.9
VII	4	8, 12, 16, 20	900,700,200,100	25.7	13.6	600	55562.1	127532.6	183094.7
VIII	4	8, 11, 14, 17	800,700,300,150	26.8	14.0	550	56218.4	115197.4	171415.8

Note: In the above Table, density of initial stocking of *Pinus elliottii* plantation was 2 500 trunks·hm^{-2}. Average price was 400 yuan per ton based on biomass of wood. Average price of resin of Jiangxi in 1999 was 3 000 yuan per ton.

From Table 2, it can be seen that the total harvest of project III was the optimal one According to market demands of wood products and byproducts in those years, corresponding economic index was determined and different effects of various thinning cutting projects was analyzed. Then, the conclusions were as follows: economic benefit was optimal by using project III in the *Pinus elliottii* plantation, its annual mean net income was up to 206.8 yuan per 667 m^2, which was more than that of construction wood management pattern (176.07 yuan per 667 m^2). At the same time, the water conservation function could be presented preferably to manage the *Pinus elliottii* plantation with this project, and it could be operated easily in practice with carrying through for three times of thinning

cutting during the whole forest management period. Therefore, the strategy of thinning cutting of project III was the optimal one.

Conclusions

Richards function could be suitably used in simulating the growth progress of *Pinus elliottii*. For *Pinus elliottii* on middle site of hilly region in Jiangxi, the average age of the trees with height of 1.3 m was 2.

Dynamic programming is adaptable to the simulation of thinning cutting of stands. Its operation is simple and the results are clear. It is an effective measure for forest management.

Pinus elliottii had been an important tree species of afforestation in Jiangxi Province and the neighborhood area in south of China. Thus studying its thinning strategy would be significant to production. Low-thinning method was the optimal measure to manage the density of the *Pinus elliottii* plantation for the multi-benefit management pattern in the hilly region of Jiangxi Province. The time of first thinning was at tree age of 8-10 years and that of final cutting was at tree age of 25. For the optimal thinning project, 3 times of thinning cutting including the first thinning should be separately conducted at tree age of 8, 12, and 16, with a thinning intensity of 950, 700, and 300 trunks per hectare, respectively. The density of 550 trunks per hectare should be preserved until the final cutting. Followed out this thinning strategy, economic benefit of the *Pinus elliottii* plantation was optimal and its annual mean net income was up to 206.8 yuan per unit of area. The water conservation function could be presented preferably to manage the *Pinus elliottii* plantation using this project too.

References

Beijing Forestry University. 1987. Forest Mensuration [M]. Beijing: China Forestry Publishing House, 53-77 (in Chinese)

Cooper, C.F. 1961. Equation for the description of past growth in ever aged stands of ponderosa pine [J]. Forest Sciences, **7**: 72-80.

Chen Xinfeng. 1997. Simulating multi-form site index curve of Japan cedar by use of Richards [J]. Journal of Beijing Forestry University, **19**(3): 8-14. (in Chinese)

Cheng Zichun, Chen Li, Wang Guangxing *et al.* 1991. Simulating system on management system of *Pinus massoniana* [M]. Beijing: China Forestry Publishing House, 52-70. (in Chinese)

Luo Qibang. 1989. Research on simulating multi-form site index model by Richards function [J]. Forest Research, **2**(6): 534-539.

Wang Qingchun, Cheng Zichun, Li Dong. 2000. Optimal stand density management on *Pinus elliottii* forest for timber and resin production [J]. Journal of Henan Agricultural University, **34**(4): 376-380. (in Chinese)

Wang Qingchun, Li Dong, Wu Nansheng, *et al.* 2001. Suitable management density of the multi-benefit management pattern in *Pinus elliottii* plantation on the upland of Jiangxi Province [J]. Chinese Journal of Applied Ecology, **12**(5): 663-666. (in Chinese)